PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H02H 3/00, 7/00, H02J 1/10 | A1

(11) International Publication Number: WO 98/09359

(43) International Publication Date: 5 March 1998 (05.03.98)

(21) International Application Number: PCT/US97/15065

(22) International Filing Date: 26 August 1997 (26.08.97)

(30) Priority Data:
08/703,412 26 August 1996 (26.08.96) US

(71) Applicant: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA [US/US]; Business & Patent Law, Mail Stop D412, Los Alamos, NM 87545 (US).

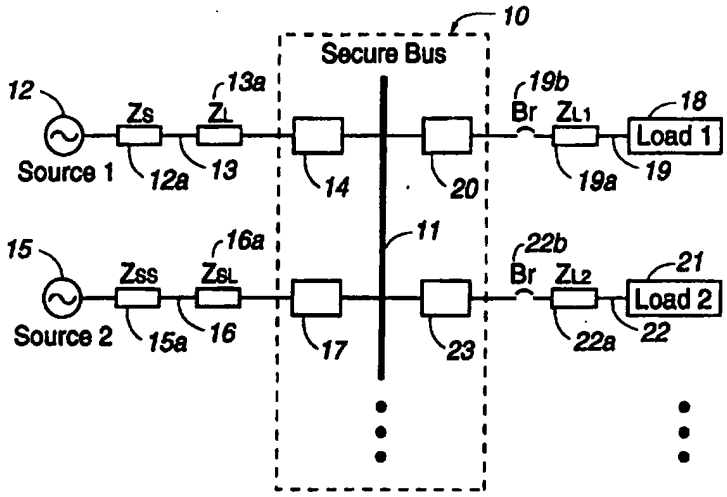
(71)(72) Applicants and Inventors: BOENIG, Heinrich, J. [US/US]; 8 La Rosa Court, Los Alamos, NM 87544 (US). CONRAD, Stephen, P. [US/US]; 5304 Ironwood Drive N.W., Albuquerque, NM 87114-4630 (US). JONES, William, H. [US/US]; P.O. Box 2221, Corrales, NM 87048 (US).

(74) Agents: WYRICK, Milton, D. et al.; Los Alamos National Laboratory, Mail Stop D412, Los Alamos, NM 87545 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: SECURE VOLTAGE BUS



(57) Abstract

A secure bus apparatus and method are provided comprising an electrically conductive bus (10) with at least two electrical power sources (12, 15) and at least one electrical load (18). At least three fast circuit breakers (14, 17, 20, 23) are connected to the electrically conductive bus for connecting the at least two electrical power sources and the at least one electrical load to the electrical conductive bus and for operating within one cycle to interrupt fault currents. This assures that a secure voltage is supplied to the at least one electrical load which is connected to the electrically conductive bus.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

SECURE VOLTAGE BUS

FIELD OF THE INVENTION

The present invention generally relates to electrical utility system buses, and, more specifically, to an apparatus and method for providing buses which maintain a generally constant voltage to its loads. This invention was made with Government support under Contract No. W-7405-ENG-36 awarded by the U.S. Department of Energy. The Government has certain rights in the invention.

Electrical utility systems are encountering requirements to provide extremely stable voltages to some of its customers. Currently, the number of electrical loads served by an electric utility which demand such stable electrical supplies is growing, due to the increasing sophistication of many manufacturing processes. Unstable electrical supplies can shut down the manufacturing process, resulting in costly lost production. It has been estimated that a voltage sag of more than 10-15%, which lasts for a few cycles, could cause millions of dollars in lost revenue to a company involved in the manufacture of semiconductors.

The electrical utilities generally refer to a stable electrical supply to such a company as "quality power," meaning a voltage or power source which is at all times available, within a narrow tolerance range, regardless of what faults or outages might occur in the surrounding electrical system. For example, a utility considers quality power to be when the voltage at a bus providing power to a customer remains within ±10-15% of its nominal value, even if an outage or short circuit occurs on the line feeding the bus. This ±10-15% voltage fluctuation is considered acceptable even for sensitive customer loads.

The stability and security of an electrical bus voltage is affected by two major sources of disturbances: a short circuit within the system and the loss of power generation. A loss of generation will cause the bus voltage to collapse to zero, and a short circuit will cause the voltage to drop to a value which is dependent on the location of the short circuit with respect to the bus. The closer, electrically, the short is to the bus, the greater will be the voltage sag. Either of these possibilities can easily cause the voltage at the bus to sag below the 10-15% requirement for sensitive loads.

Utility systems currently use either mechanical breakers, or fast interrupting fuses to protect against short circuits. The mechanical breakers require three to five cycles (50 to 83

ms) to open, in addition to about one cycle for the fault detection by relays. This period is long enough to allow the voltage to sag to a level which will be sufficiently low to trip sensitive loads. The fast interrupting fuses interrupt a fault current in less than a cycle, but cannot be restored immediately, because replacement of the associated fuse requires time and labor.

In a copending U.S. Patent application entitled Fault Current Limiter and Alternating Current Circuit Breaker, filed May 8, 1996, and bearing serial number 08/646,836, the applicant herein disclosed a current limiter and ac circuit breaker which can operate within one cycle. The circuit breaker also is capable of limiting the short circuit current and the voltage sag within the first cycle after a fault. Because this invention operates so quickly, it, as well as other fast circuit breakers, can form a part of the present invention, allowing it to perform its intended function.

It is therefore an object of the present invention to provide an electrical bus for use at voltage levels of 12-15 kV or lower which can provide a secure voltage which will remain within 10-15% of its nominal value.

It is another object of the present invention to provide electrical bus apparatus which is not materially affected by short circuits or other fault conditions in the circuits attached to the electrical bus apparatus.

Additional objects, advantages and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

SUMMARY OF THE INVENTION

To achieve the foregoing and other objects, a secure bus apparatus comprises an electrically conductive bus with at least two electrical power sources, and at least one electrical load. At least three fast circuit breaker means are connected to the electrically conductive bus for connecting the at least two electrical power sources and the at least one electrical load to the electrically conductive bus and for operating within one (1) cycle to interrupt fault currents. This assures that a secure voltage is supplied to the at least one electrical load.

In a further aspect of the present invention, a method of providing a secure electrical bus comprises the steps of providing an electrical bus;

connecting at least two electrical power sources to the electrical bus through at least one fast circuit breaker; and connecting at least one electrical load to the electrical bus through at least one fast circuit breaker.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate the embodiments of the present invention and, together with the description, serve to explain the principles of the invention. In the drawings:

FIGURE 1 is a schematical illustration of an embodiment of the present invention in which a bus is connected to two sources of electrical power and two loads through fast circuit breakers.

FIGURE 2 is a schematical illustration of another embodiment of the present invention in which an independent energy source is connected to the bus, in this case, a superconducting magnetic energy storage system.

FIGURE 3 is a schematical illustration of a fast acting fuse installed between the bus and the fast circuit breaker for fault protection purposes.

DETAILED DESCRIPTION

The present invention provides a secure electrical bus applicable for substation class medium voltages (12-15 kV) or lower through the application of components to a bus which allow for the provision of stable electrical power to critical loads. The invention can be understood most easily through reference to the drawings.

In Figure 1, an embodiment of secure bus 10 according to the present invention is schematically illustrated. As shown bus 11 is primarily powered by electrical source 12 through transmission line 13, and the associated impedances, Z_S 12a and Z_L 13a, and fast circuit breaker 14. Z_S 12a represents the internal impedance of electrical source 12, and Z_L 13a represents the inherent impedance of transmission line 13.

Secondary electrical source 15 is also connected to bus 11, representing any of numerous sources of electrical power as will be hereinafter described. Secondary electrical source 15 is connected to bus 11 through its internal impedance, Z_{SS} 15a, transmission line 16 and its inherent impedance, Z_{SL} 16a, and fast circuit breaker 17.

Load 18 is connected to bus 11 through transmission line 19 and its inherent impedance, Z_{L1} 19a, conventional breaker or disconnect 19b, and fast circuit breaker 20. Likewise, load 21 is connected to bus 11 through transmission line 22 and its inherent impedance, Z_{L2} 22a, conventional breaker or disconnect 22b, and through fast circuit breaker 23. Although Figure 1 illustrates only two loads 18, 21 for clarity, an actual bus 11 could have only one or many more loads, all of which would be connected as is illustrated for loads 18, 21.

Fast circuit breakers 14, 17, 20 and 23 should be capable of isolating a short circuit within 1 cycle. The invention disclosed in the above-described copending patent application can operate this quickly. This breaker is able to operate this quickly through a novel connection of thyristors and large inductors for actually diverting fault current through the inductors in the manner disclosed in the copending patent application. Additionally, fast circuit breakers manufactured by WESTINGHOUSE® and others also can be used if they meet this requirement. It is this ability of fast circuit breakers 16, 19, and 22 to isolate a fault in less than one cycle, not allowing the voltage of the bus to drop below an allowable range, that allows the present invention to provide a secure bus 10.

Figure 2 illustrates a similar arrangement in which an independent energy source 24 is employed in place of secondary energy source 15, transmission line 16, the impedances 15a, 16a, and fast circuit breaker 17. The removal of the transmission line and fast circuit breaker is allowed because any independent energy source 24 would be located in close proximity to bus 11.

The use of some type of independent energy source 24 located at the site of bus 11 often will be required for operation of the present invention, because, with the complex interconnected power systems currently in place, an independent, conventional secondary energy source 18 could be difficult to obtain. Independent energy source 24 must be capable of storing a substantial quantity of electrical energy and of delivering that energy to bus 11 quickly on demand. Examples of appropriate independent energy sources 24 include inertial, capacitive, magnetic, battery, or other storage methods. Each of these energy storage methods has its own advantages and disadvantages for particular applications, resulting from particular energy and power requirements.

Capacitive energy storage has certain advantages in the high power, short duration application with energies in the 1 to 10 MJ range using computer-grade aluminum

electrolytic or high energy density, self-healing capacitors. These capacitors used in a capacitive storage system have a long life expectancy, are completely static, and operate at room temperatures. They also are extremely efficient, and lose only a small amount of charge over a relatively long period of time. Appropriate conventional power conversion equipment would be required with this system to convert the capacitor output to the alternating current required for bus 11.

Another appropriate independent energy source 24 could be a superconducting magnetic energy system (SMES). A SMES unit typically can provide approximately several hundred MJ. Of course, these systems require cryogenic systems to cool the superconducting coils, rendering them more complex and expensive than the capacitive storage systems, but, nonetheless, they are attractive for higher power installations.

Banks of batteries or inertial power sources can also be used if appropriate for the particular. With batteries, a trickle charge obtained from the power grid would keep the batteries charged until they would be needed to provide a short burst of electrical power to bus 11. As with the above-described capacitive system, conventional power conversion equipment would be required to convert the direct current of the batteries to the alternating current required for bus 11.

Somewhat similarly, the power grid could keep an inertial source rotating until a fault causes the power grid to be disconnected and power to be provided from the inertial source to bus 11 for a short period of time.

With inertial systems, the power grid would provide the necessary power to get the high mass system to its design rotational speed. Once this speed is attained, the input power can be cut back to a point which maintains that speed by compensating for frictional losses.

Upon the occurrence of a power outage or a fault on transmission line Z_L 13a, the power grid is disconnected and power is provided from the inertial system to maintain the voltage on bus 11 until the affected fast circuit breaker 14 operates to interrupt the fault current or until the power from source 12 is restored. Once again, as with the capacitive and battery systems, the inertial system also requires conventional power conversion equipment to convert the inertial system output to the alternating current required for bus 11.

For a fault on transmission line Z_L 13a, it is fast circuit breaker 14 which enables the present invention to require only the brief provision of electrical power either from

secondary electrical source 15 or independent energy source 24. The fact that fast circuit breaker 14 operates within one cycle of the occurrence of a fault and extinguishes the fault current means that independent energy source 24 only will need to provide power to bus 11 for that short period of time.

For the system illustrated in Figure 1, the voltage of bus 11 remains within the allowable tolerance range of 10-15%, even if short circuits occur on transmission lines 13, 16, 19 or 22, or within loads 18, 21, or source 12. This is due to the extremely fast operation of fast circuit breakers 14, 20, 23.

Fast circuit breakers 14, 17, 20 and 23 must be capable of interrupting fault current flow within one cycle. At the present time there are only a few such breakers. One such breaker is made by WESTINGHOUSE® and is a solid state device which is reported to interrupt current flow in approximately one quarter (¼) cycle. This breaker utilizes a pair of anti-parallel gate-turn-off thyristors, which inherently limit the current rating of the breaker.

Another breaker, which still is in the experimental range, employs a new semiconductor, known as a MTO, which is a cross between a transistor and a thyristor, having the ability to interrupt currents. This breaker should also have a short interrupt time, but is likely also to be limited in the amount of current it can interrupt.

Currently, the best choice as a fast circuit breaker 14 is the breaker disclosed in the above-described patent application. The fault current interrupter disclosed therein has a high current interrupt rating, and can interrupt the fault current in less than one (1) cycle.

The embodiments of the present invention, as illustrated in Figures 1 and 2, do not represent the concept of an uninterruptible power supply (UPS), which serves to protect only against power source outages by providing a secondary power source. The present invention does accomplish this function of a UPS, but, in addition, protects against short circuits on bus 11, as well as faults on transmission lines 13, 16, and transmission lines 19, 22, all the while maintaining the voltage at bus 11 within ±10-15% of its rated value. If fast circuit breakers 14, 17, 20, and 23 are the fault current interrupters disclosed in the above-described patent application, and a fault occurs, fast circuit breakers 14, 17, 20 and/or 23 will operate within less than one cycle to reduce the current in the affected transmission line to an extremely small value (essentially zero)restoring the voltage at bus 11 to its original value. During the one cycle opening time of fast circuit breakers 14, 17, 20, and 23, an

inductor is inserted into the current path, limiting the voltage drop. Effectively, this means that a fault at any load location would cause the affected fast circuit breaker 20 or 23 to operate, replacing the load with the inductance of the fault current interrupter fast circuit breaker 20 or 23. Therefore, with respect to bus 11, the load, for all practical purposes, does not change.

In the unlikely event that a fast circuit breaker 14, 17, 20 or 23 should fail, a fast acting fuse 31 could be installed between each fast circuit breaker 14, 17, 20 and 23 and bus 11, as illustrated in Figure 3. The action of fast acting fuse 31, would disconnect the branch circuit with the malfunctioning fast circuit breaker 14, 17, 20, or 23. Of course, fast acting fuse 31 would totally disconnect the affected line from bus 11, but other connected loads would still be served by bus 11.

The foregoing description of the preferred embodiments of the invention have been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims appended hereto.

WHAT IS CLAIMED IS:

1. A secure bus apparatus for use at substation class medium voltages and lower comprising:

an electrically conductive bus;

at least two electrical power sources;

at least one electrical load;

at least three fast circuit breaker means connected to said electrically conductive bus for connecting said at least two electrical power sources and said at least one electrical load to said electrically conductive bus and for operating within one (1) cycle to interrupt fault currents;

wherein a secure voltage is supplied to said at least one electrical load.

2. The secure electrical bus as described in Claim 1, wherein said at least three fast circuit breakers comprise at least three fault current interrupters.

3. The secure electrical bus as described in Claim 1, wherein said at least two electrical power sources comprise two conventional electrical generators.

4. The secure electrical bus as described in Claim 1, wherein said at least two electrical power sources comprise a conventional electrical generator and an independent electrical power source.

5. The secure electrical bus as described in Claim 4, wherein said independent electrical power source comprises a superconducting magnetic energy source.

6. The secure electrical bus as described in Claim 4, wherein said independent electrical power source comprises a bank of capacitors connected to power conversion equipment.

7. The secure electrical bus as described in Claim 4, wherein said independent electrical power source comprises a bank of batteries connected to power conversion equipment.

8. The secure electrical bus as described in Claim 4, wherein said independent electrical power source comprises an inertial energy storage system connected to power conversion equipment.

9. The secure electrical bus as described in Claim 1, wherein said at least one electrical load comprises one electrical load.

10. A method of providing a secure electrical bus comprising the steps of:

providing an electrical bus;

connecting at least two electrical power sources to said electrical bus through at least one fast circuit breaker;

connecting at least one electrical load to said electrical bus through at least one fast circuit breaker.

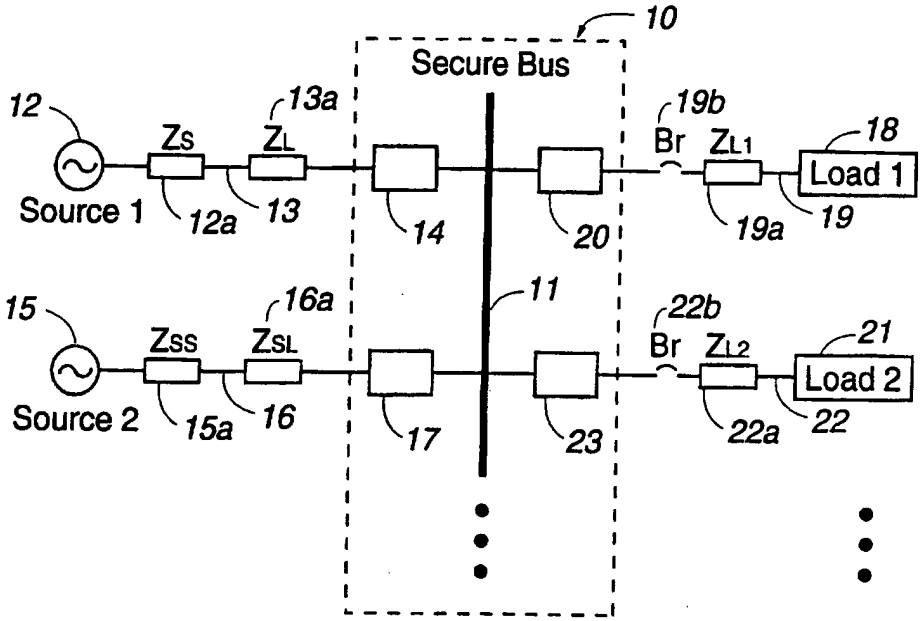

10
Secure Bus
12
Zs
13a
ZL
19b
Br
ZL1
18
Load 1
Source 1
12a
13
14
20
19a
19
15
Zss
16a
ZSL
11
22b
Br
ZL2
21
Load 2
Source 2
15a
16
17
23
22a
22

Fig. 1

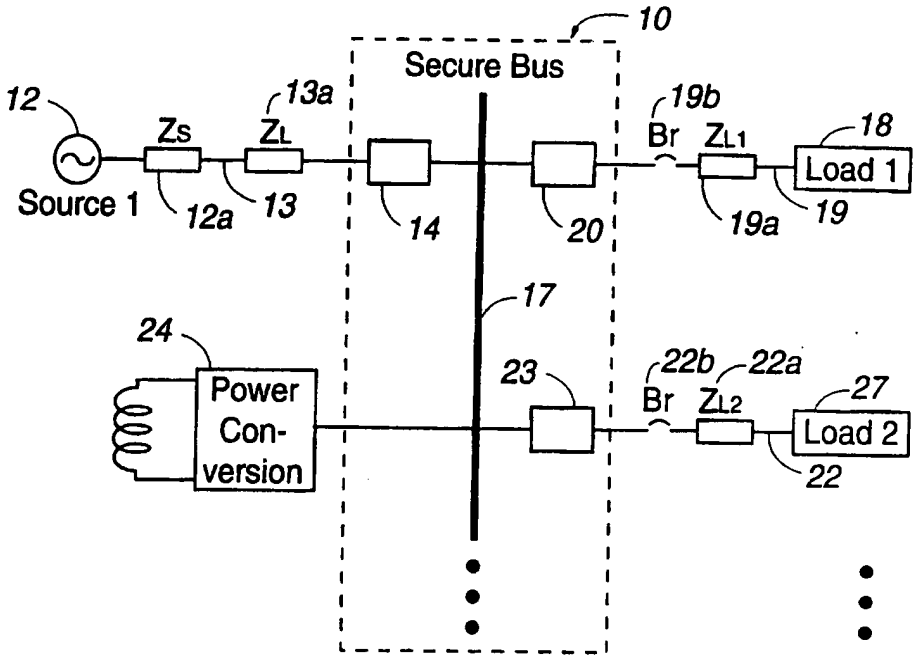

10
Secure Bus
12
Source 1
Zs
12a
13a
ZL
13
14
20
19b
Br
ZL1
19a
18
Load 1
19
17
24
Power
Con-
version
23
22b
22a
Br
ZL2
27
Load 2
22

Fig. 2

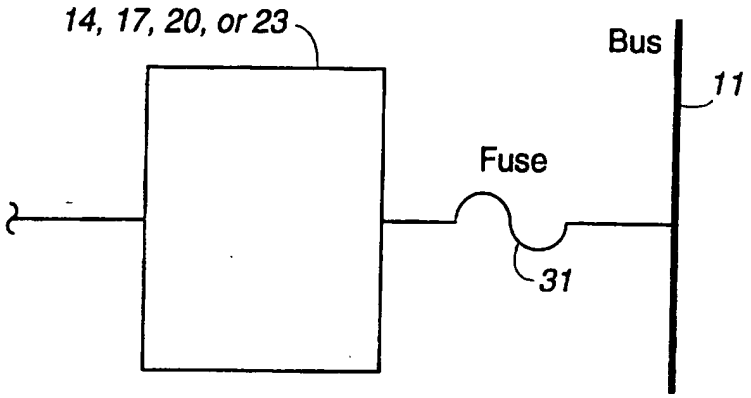


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/15065

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :H02H 3/00, 7/00; H02J 1/10
US CL :361/63; 307/19, 23
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 361/62, 63; 307/18, 19, 23, 29

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,428,022 A (ENGEL et al.) 24 JANUARY 1984, col. 4, lines 19-25; col. 5, lines 30-40.	1-10
Y	US 5,301,507 A (LASKARIS et al.) 12 APRIL 1994, col. 1, line 67 - col 2, line 3.	5,6,8
Y	US 5,550,476 A (LAU et al.) 27 AUGUST 1996, col. 2, lines 40-45.	5,6,8
Y	US 5,561,579 A (GYUGYI et al.) 01 OCTOBER 1996, col. 1, lines 46-67; col. 2, lines 1-10.	1-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
11 OCTOBER 1997

Date of mailing of the international search report
02 DEC 1997

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703) 305-3230

Authorized officer
MICHAEL J SHERRY
Telephone No. (703) 308-1680

Form PCT/ISA/210 (second sheet)(July 1992)*